The acute and chronic effects of bullectomy on cardiovascular function at rest and during exercise

Nathaniel Marchetti, DO,[a] Katharine T. Criner, BS,[b] Michael F. Keresztury, MD,[c] Satoshi Furukawa, MD,[d] and Gerard J. Criner, MD,[a] Philadelphia, Pa

Supplemental material is available online.

Video clip is available online.

Although bullectomy has been shown to decrease dyspnea, work of breathing, residual volume, and total lung capacity and improve respiratory muscle function, its effect on cardiovascular performance is relatively unknown.[1-3] Herein, we describe the immediate and long-term effects of bullectomy on cardiac function.

Clinical Summary

A 42-year-old actively smoking man with a history of chronic obstructive pulmonary disease and intractable dyspnea was referred for bullectomy. Physical examination revealed tachypnea without evidence of jugular venous distension or hepatojugular reflex. The cardiac examination was unremarkable, except for an inferomedially displaced point of maximal impulse. His chest was hyperinflated, with decreased breath sounds in the right hemithorax.

While getting onto the computed tomographic scan table, the patient experienced severe acute respiratory distress and nearly had a respiratory arrest. The patient was transferred to the emergency department, stabilized, and admitted to complete the preoperative evaluation. A chest radiogram (Figure E1, *A*) displayed a massive right bulla with tension, inverting the right diaphragm, compressing residual right lung tissue, and displacing the heart leftward. The results of pulmonary function testing, cardiopulmonary exercise testing, and echocardiography are displayed in Tables E1 and E2. The patient was considered at high risk for respiratory failure without surgical intervention and underwent bullectomy after optimization of respiratory medications.

Operative procedure and hospital course. The patient underwent video-assisted thoracoscopic removal of the bulla, but because of the size of the bulla, the procedure was converted to an open thoracotomy. A pulmonary artery catheter was placed to guide fluid management perioperatively. On opening the chest, a giant bulla was found to occupy nearly the entire right hemithorax, with atelectasis of the remaining lung tissue (see online video). A bullectomy was performed using careful sharp and blunt dissections and a staple gun. The postoperative recovery was uneventful.

Effect of bullectomy on cardiac and respiratory physiology. Immediately after bullectomy and reinflation of the right lung, there was a dramatic improvement in cardiac output, cardiac index, and stroke volume. Specifically, stroke volume and cardiac index more than doubled (Table 1). Additionally, there was a decrease in total pulmonary resistance (TPR) and systemic vascular resistance. Pulmonary vascular resistance could not be calculated because the pulmonary artery catheter could not be maintained in the wedge position. Because a preoperative transthoracic echocardiogram provided suboptimal views of cardiac structure, transesophageal echocardiographic studies were performed in the operating room before and after bullectomy. Immediately after bullectomy, the right ventricular function and visualization of cardiac structures improved (Table E2). Pulmonary function testing and cardiopulmonary exercise testing was repeated 9 months after bullectomy (Table E1). The forced expiratory volume in 1 second improved 122%, whereas the residual volume decreased by 40%. After bullectomy, exercise time increased by 87%, and work tolerance increased by 143%. Preoperatively, the O_2 pulse (a noninvasive marker for cardiac output) calculated by dividing the oxygen uptake by the heart rate and multiplying by 1000, reached an early plateau, but 9 months after surgical intervention, the oxygen pulse did not plateau during exercise (Figure 1). The chest radiographic analysis 6 months postoperatively (Figure E1, *B*) exhibited a reinflated right lung with return of cardiac structures to the midline position.

Discussion

Our case exemplifies how removal of a massive bulla improves cardiovascular performance in addition to its established beneficial effects on respiratory mechanics. After bullectomy, the patient had significant improvements in exercise time, cardiac output, cardiac index, stroke volume, TPR, systemic vascular resistance, and right ventricular function.

Bullectomy should improve TPR by increasing the pulmonary vascular bed through recruitment of viable pulmonary vessels that had been compressed by the presence of a giant bulla. Our data

From the Departments of Medicine, Division of Pulmonary and Critical Care Medicine,[a] Anesthesiology,[c] and Surgery, Division of Cardiac and Thoracic Surgery,[d] Temple University School of Medicine,[b] Philadelphia, Pa.

Received for publication July 25, 2007; accepted for publication Aug 15, 2007.

Address for reprints: Nathaniel Marchetti, DO, Division of Pulmonary and Critical Care Medicine, Temple University School of Medicine, 745 Parkinson Pavilion, 3401 North Broad St, Philadelphia Pa 19140 (E-mail: nathaniel.marchetti@tuhs.temple.edu).

J Thorac Cardiovasc Surg 2008;135:205-6

0022-5223/$34.00

doi:10.1016/j.jtcvs.2007.08.036

Table 1. Acute effects of bullectomy on hemodynamics

	Preoperative, chest closed	Intraoperative, lung reinflated and chest closed
RA, mm Hg	11	10
PAS, mm HG	32	37
PAD, mm HG	16	22
mPAP, mm Hg	21	27
CO, L/min	3.6	6.0
CI, L/m^2	1.6	3.8
SV, mL	42	83
TPR, dynes $\cdot s^{-1} \cdot cm^{-2}$	424	360
SVR, dynes $\cdot s^{-1} \cdot cm^{-2}$	1555	733
MAP, mm Hg	81	65
HR, beats/min	86	72

RA, Right atrial pressure; *PAS*, pulmonary artery pressures, systolic; *PAD*, pulmonary artery pressures, diastolic; *mPAP*, mean pulmonary artery pressure; *CO*, cardiac output; *CI*, cardiac index; *SV*, stroke volume; *TPR*, total peripheral resistance; *SVR*, systemic vascular resistance; *MAP*, mean arterial pressure; *HR*, heart rate.

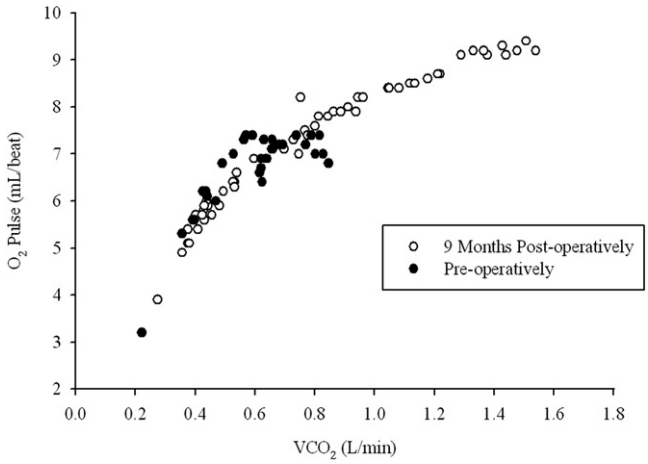

Figure 1. The effect of bullectomy on oxygen pulse measurement during cardiopulmonary exercise testing. After bullectomy, the patient was able to achieve a significantly higher oxygen pulse. *VCO_2*, Carbon dioxide production.

support this by showing an immediate improvement in right ventricular function, resulting in increased cardiac output accompanied by a reduction in TPR. Follow-up pulmonary function testing showed an improved diffusion capacity, suggesting an increase in pulmonary vascular bed area after bullectomy. Resection of emphysematous lung tissue has been shown to have favorable effects on left ventricular dimensions and cardiac output,[4] and in our case the return of cardiac structures to a normal geometry and anatomic position contributed to the immediate improvement in cardiac function because of improved venous return.

To our knowledge, this is the first detailed report of the acute and chronic effect of bullectomy on cardiopulmonary physiology. These improvements are likely caused by improved venous return, recruitment of viable pulmonary vasculature (thus decreasing TPR), and improved geometry of the heart. When evaluating a patient for bullectomy, its potential for improving both cardiac and pulmonary function should be considered and factored into the decision as to whether and when to surgically intervene.

References

1. Schipper PH, Meyers BF, Battafarano RJ, Guthrie TJ, Patterson GA, Cooper JD. Outcomes after resection of giant emphysematous bullae. *Ann Thorac Surg*. 2004;78:976-82.
2. Teramoto S, Fukuchi Y, Nagase T, Matsuse T, Shindo G, Orimo H. Quantitative assessment of dyspnea during exercise before and after bullectomy for giant bulla. *Chest*. 1992;102:1362-6.
3. Travaline JM, Addonizio VP, Criner GJ. Effect of bullectomy on diaphragm strength. *Am J Respir Crit Care Med*. 1995;152:1697-701.
4. Jorgensen K, Houltz E, Westfelt U, Nilsson F, Schersten H, Ricksten SE. Effects of lung volume reduction surgery on left ventricular diastolic filling and dimensions in patients with severe emphysema. *Chest*. 2003;124:1863-70.

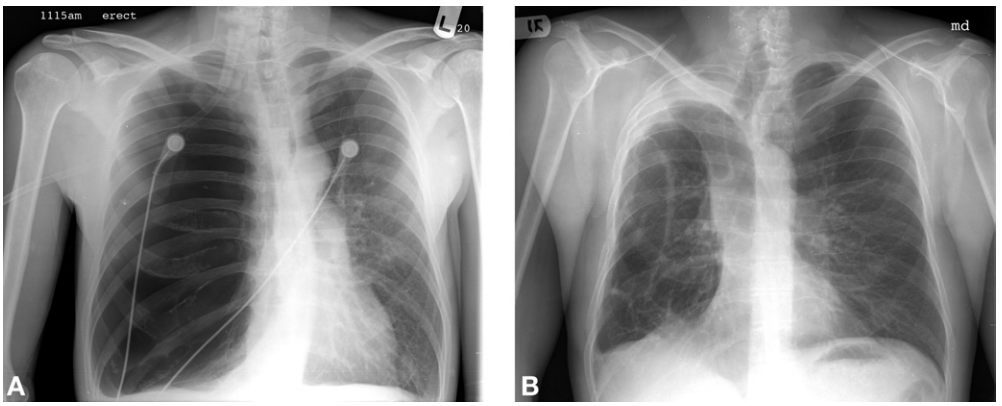

Figure E1. A, Posteroanterior view chest radiogram at time of admission. A giant bulla on the right compresses the right lung. Hyperinflation of the chest with a flattened diaphragm, widened intercostal spaces, horizontal ribs, and moderate leftward shift of the mediastinum are readily apparent. B, Posteroanterior view chest radiogram 6 months after bullectomy shows a reinflated right lung. The positions of the mediastinum and diaphragm have returned to the normal midline positions.

Table E1. Pulmonary function results preoperatively and 9 months after bullectomy and percentage change versus preoperative and postoperative results

	Preoperative (% predicted)	9 mo Postoperative (% predicted)	Change (%)
Spirometry			
FVC (L)	1.89 (41)	3.82 (83)	+104
FEV_1 (L)	0.78 (22)	1.73 (45)	+122
FEV_1/FVC (%)	41	45	+10
Body plethysmography			
TLC (L)	6.81 (108)	6.73 (107)	−2
RV (L)	4.77 (280)	2.89 (163)	−40
Helium dilution			
TLC (L)	3	ND	
DLco ($mL \cdot mm\ Hg^{-1} \cdot min^{-1}$)	11.4 (32)	13.1 (37)	+15
Exercise performance			
Total exercise time (min)	10	18.67	+87
Work (W)	35	85	+143
Vo_2 max (L/min)	0.854 (30)	1.29 (61)	+51
Vco_2 max (L/min)	0.867	1.518	+75
V_E max (L)	25.7	58	+125
O_2 pulse at max exercise (mL/beat)	6.8	9.2	+35
Peak heart rate (beats/min)	105 (61)	141 (80)	+33
Reason for termination	Severe dyspnea	Severe dyspnea	—

FVC, Forced vital capacity; *FEV_1*, forced expiratory volume in 1 second; *TLC*, total lung capacity; *RV*, residual volume; *ND*, not done; *DLco*, lung diffusion capacity; *Vo_2*, oxygen capacity; *Vco_2*, carbon dioxide production; *V_E*, minute ventilation; *MVV*, maximum voluntary ventilation.

Table E2. Transesophageal echocardiographic analysis intraoperatively before and after bullectomy

	Preoperative TTE	Intraoperative prebullectomy TEE	Intraoperative postbullectomy TEE
Visualization of heart	Poor	Poor	Improved
RV function	Mildly dilated with mildly reduced function	Dilated with moderate hypokinesis	Dilated but improved function
LV function	Normal EF: 55% to 65%	Low normal EF: 40% to 50%	Low normal EF: 40% to 50%

TTE, Transthoracic echocardiography; *TEE*, transesophageal echocardiography; *RV*, right ventricular; *LV*, left ventricular.